

NOx Control Cost Effectiveness Estimate

Engine Manufacturer	General Electric
Model No.	LM 1600
Unit ID	12A
Fuel Used	Natural Gas
Emissions Control	SCR
Combustion Control Purpose	NOx
Target Reduction	95%

Color Legend

User Data / Information Input Cell
"Cumulative" Cost Cell for Primary Categories
Cost Effectiveness (\$ / ton)

1 Engine Design Conditions

Power Output	19200	(hp)	Comments
Engine Exhaust Temperature		(F)	Rated HP
Engine Exhaust Rate		(lb/hr)	optional input
Gas Volume		(dscfm)	optional input

2 Full Load Engine Exhaust Composition:

Oxygen (O ₂)		(vol. %)	Comments
Carbon Dioxide (CO ₂)		(vol. %)	optional input
Water (H ₂ O)		(vol. %)	optional input
Oxides of Nitrogen (NOx)		(ppmvd)	optional input
Nitrogen (N ₂)		(vol. %)	optional input
NOx	52.7 lb/hr	0.366 (lb/MMBtu)	NOx emissions from test Data: 373.0 lb/MMSCF ~0.37 lb/MMBtu

3 Engine Parameters

Total Operating Hours per Season	8760	(hrs)	100% utilization	Comments
----------------------------------	------	-------	------------------	----------

4 Final Exhaust Gas Composition

Oxides of Nitrogen (NOx)	2.6 lb/hr	0.018 (lb/MMBtu)	Assume 75% reduction
--------------------------	-----------	------------------	----------------------

5 Economic Parameters

Source of Cost Data	see Analysis	Analysis primarily relying on EPA Cost Manual
---------------------	--------------	---

Direct Costs	Cost Formula	Comments
Combustion Control Equipment and Auxiliary Equipment	\$3,712,500 (A)	Based on EPA control cost manual (\$167/kw; adjust to 2020\$)
Instrumentation	\$371,250 (0.1*A)	Calculated Cost using EPA Control Cost Manual
Sales Taxes	\$0 (0.03*(A+instrumentation))	3% Sales Tax in this example
Freight	\$185,625 (0.05*A)	Calculated Cost using EPA Control Cost Manual
Purchased Equipment Cost (PEC)	\$4,269,375	PEC

6 Direct Installation Costs

Direct Installation Costs	Cost Formula	Comments
Foundations and Supports	\$341,550 (0.08*PEC)	Calculated Cost using EPA Control Cost Manual
Handling and Erection	\$597,710 (0.14*PEC)	Calculated Cost using EPA Control Cost Manual
Electrical	\$170,780 (0.04*PEC)	Calculated Cost using EPA Control Cost Manual
Piping	\$85,390 (0.02*PEC)	Calculated Cost using EPA Control Cost Manual
Insulation for ductwork	\$42,690 (0.01*PEC)	Calculated Cost using EPA Control Cost Manual
Painting	\$42,690 (0.01*PEC)	Calculated Cost using EPA Control Cost Manual
Site Preparation	\$0 SP	As required
Buildings	\$0 Bldg	As required
Total Installation Cost (TIC)	\$1,280,810	
Total Direct Costs (PEC+TIC)	\$5,550,185	

7 Indirect Costs

Indirect Costs	Cost Formula	Comments
Engineering	\$426,938 (0.10*PEC)	Calculated Cost using EPA Control Cost Manual
Construction and field expenses	\$213,469 (0.05*PEC)	Calculated Cost using EPA Control Cost Manual
Contractor fees	\$426,938 (0.10*PEC)	Calculated Cost using EPA Control Cost Manual
Start-up	\$85,388 (0.02*PEC)	Calculated Cost using EPA Control Cost Manual
Performance test	\$42,694 (0.01*PEC)	Calculated Cost using EPA Control Cost Manual
Contingencies	\$128,081 (0.03*PEC)	Calculated Cost using EPA Control Cost Manual
Total Indirect Costs (IC)	\$1,323,506 (0.31*PEC)	

8 Capital Cost Summary

Total Direct Capital Costs (DC)	\$5,550,185	Comments
Total Indirect Capital Costs (IC)	\$1,323,506	
Total Capital Investment (TCI)	\$6,873,691	

9 Direct Annual Costs

Direct Annual Costs	Cost Formula	Comments
Operator Labor	\$12,500 nominal cost	0.5 hr/shift; example from similar EPA analysis
Supervisor Labor	\$1,875	15% of operator
Operating Materials - ammonia	\$54,289	materials estimate annual NH3 at \$700 per ton; 1.1 molar ratio
Maintenance - Labor	\$12,500 nominal cost	0.5 hr/shift; rate example from EPA
Maintenance - Materials	\$5,000 nominal cost	Engineering Estimate
Catalyst maintenance / replacement	\$185,625	Engineering Estimate (5% of Cap Cost)
Testing and QA/QC	\$20,000	Engineering estimate - Annual test; reagent controller QA
Electricity	\$2,500	Estimate based on analysis in PA DEP TSD
Total Direct Annual Costs	\$294,289	

10 Indirect Annual Costs

Indirect Annual Costs	Cost Formula	Capital Recovery Factor	Comments
Overhead	\$19,125 (0.6*(OL+SL+ML+MM))		Engine ACT Document
Administrative Charges	\$137,474 (0.02*TCI)		Engine ACT Document
Property Taxes	\$68,737 (0.01*TCI)		
Insurance	\$68,737 (0.01*TCI)		
Capital Recovery	\$362,244 CRF[TCI]	CRF 0.0527	Factor for costs annualized over 20 years at 5% interest.
Total Indirect Annual Costs	\$656,316		

20.0000	30.0000
0.0500	0.0325
0.0802	0.0527

CRF = $i * (1+i)^n / [(1+i)^n - 1]$ (i expressed as a decimal - e.g., 10% = 0.1)

11 Summary

Summary	Comments
Total Direct Annual Operating Costs	\$294,289
Total Indirect Annual Operating Costs	\$656,316
Total Annual Costs	\$950,605
Incremental Annual Costs Over Baseline	\$950,605

12 Annual Emissions Reduction Over Baseline

Oxides of Nitrogen (NOx)	219.30 (Tons)	Comments
--------------------------	---------------	----------

Cost Effectiveness (\$/Ton)	Comments
Oxides of Nitrogen (NOx)	\$4,335

NOx Control Cost Effectiveness Estimate

Engine Manufacturer Model No. Unit ID Fuel Used Emissions Control Combustion Control Purpose Target Reduction		Cooper-Rolls Avon 12B Natural Gas SCR NOx 95%		* per WESTAR O&G report		Color Legend User Data / Information Input Cell "Cumulative" Cost Cell for Primary Categories Cost Effectiveness (\$ / ton)		
1 Engine Design Conditions						Comments		
Power Output		14300	(hp)			Rated HP		
Engine Exhaust Temperature			(F)			optional input		
Engine Exhaust Rate			(lb/hr)			optional input		
Gas Volume			(dscfm)			optional input		
2 Full Load Engine Exhaust Composition:						Comments		
Oxygen (O ₂)			(vol. %)			optional input		
Carbon Dioxide (CO ₂)			(vol. %)			optional input		
Water (H ₂ O)			(vol. %)			optional input		
Oxides of Nitrogen (NOx)			(ppmvd)			optional input		
Nitrogen (N ₂)			(vol. %)			optional input		
NOx		23.1 lb/hr	0.170 (lb/MMBtu)	NOx emissions from test Data: 173.9 lb/MMSCF ~0.170 lb/MMBtu				
3 Engine Parameters						Comments		
Total Operating Hours per Season		8760	(hrs)	100% utilization				
4 Final Exhaust Gas Composition						Comments		
Oxides of Nitrogen (NOx)		1.2 lb/hr	0.009 (lb/MMBtu)	Assume 75% reduction				
5 Economic Parameters						Comments		
Source of Cost Data		see Analysis	Analysis primarily relying on EPA Cost Manual					
Direct Costs		Cost Formula			Comments			
Combustion Control Equipment and Auxiliary Equipment		\$2,765,000	(A)	Based on EPA control cost manual (\$167/kw; adjust to 2020\$)				
Instrumentation		\$276,500	(0.1*A)	Calculated Cost using EPA Control Cost Manual				
Sales Taxes		\$0	(0.03*(A+instrumentation))	3% Sales Tax in this example				
Freight		\$138,250	(0.05*A)	Calculated Cost using EPA Control Cost Manual				
Purchased Equipment Cost (PEC)		\$3,179,750	PEC					
Direct Installation Costs		Cost Formula			Comments			
Foundations and Supports		\$254,380	(0.08*PEC)	Calculated Cost using EPA Control Cost Manual				
Handling and Erection		\$445,170	(0.14*PEC)	Calculated Cost using EPA Control Cost Manual				
Electrical		\$127,190	(0.04*PEC)	Calculated Cost using EPA Control Cost Manual				
Piping		\$63,600	(0.02*PEC)	Calculated Cost using EPA Control Cost Manual				
Insulation for ductwork		\$31,800	(0.01*PEC)	Calculated Cost using EPA Control Cost Manual				
Painting		\$31,800	(0.01*PEC)	Calculated Cost using EPA Control Cost Manual				
Site Preparation		\$0	SP	As required				
Buildings		\$0	Bldg	As required				
Total Installation Cost (TIC)		\$953,940						
Total Direct Costs (PEC+TIC)		\$4,133,690						
Indirect Costs		Cost Formula			Comments			
Engineering		\$317,975	(0.10*PEC)	Calculated Cost using EPA Control Cost Manual				
Construction and field expenses		\$158,988	(0.05*PEC)	Calculated Cost using EPA Control Cost Manual				
Contractor fees		\$317,975	(0.10*PEC)	Calculated Cost using EPA Control Cost Manual				
Start-up		\$63,595	(0.02*PEC)	Calculated Cost using EPA Control Cost Manual				
Performance test		\$31,798	(0.01*PEC)	Calculated Cost using EPA Control Cost Manual				
Contingencies		\$95,393	(0.03*PEC)	Calculated Cost using EPA Control Cost Manual				
Total Indirect Costs (IC)		\$985,723	(0.31*PEC)					
8 Capital Cost Summary						Comments		
Total Direct Capital Costs (DC)		\$4,133,690						
Total Indirect Capital Costs (IC)		\$985,723						
Total Capital Investment (TCI)		\$5,119,413						
Direct Annual Costs		Cost Formula			Comments			
Operator Labor		\$12,500	nominal cost	0.5 hr/shift; example from similar EPA analysis				
Supervisor Labor		\$1,875		15% of operator				
Operating Materials - ammonia		\$23,789		materials estimate annual NH3 at \$700 per ton; 1.1 molar ratio				
Maintenance - Labor		\$12,500	nominal cost	0.5 hr/shift; rate example from EPA				
Maintenance - Materials		\$5,000	nominal cost	Engineering Estimate				
Catalyst maintenance / replacement		\$138,250		Engineering Estimate (5% of Cap Cost)				
Testing and QA/QC		\$20,000		Engineering estimate - Annual test; reagent controller QA				
Electricity		\$2,500		Estimate based on analysis in PA DEP TSD				
Total Direct Annual Costs		\$216,414						
Indirect Annual Costs		Cost Formula			Capital Recovery Factor	Comments		
Overhead		\$19,125	(0.6*(OL+SL+ML+MM))					
Administrative Charges		\$102,388	(0.02*TCI)			Engine ACT Document		
Property Taxes		\$51,194	(0.01*TCI)			Engine ACT Document		
Insurance		\$51,194	(0.01*TCI)					
Capital Recovery		\$269,793	CRF[TCI]	CRF	0.0527	Factor for costs annualized over 20 years at 5% interest.		
Total Indirect Annual Costs		\$493,695	CRF = i * (1+i)^n / [(1+i)^n - 1] (i expressed as a decimal - e.g., 10% = 0.1)					
9 Summary						Comments		
Total Direct Annual Operating Costs		\$216,414						
Total Indirect Annual Operating Costs		\$493,695						
Total Annual Costs		\$710,109	\$50 \$ per hp					
Incremental Annual Costs Over Baseline		\$710,109						
12 Annual Emissions Reduction Over Baseline						Comments		
Oxides of Nitrogen (NOx)		96.10 (Tons)						
Cost Effectiveness (\$/Ton)						Comments		
Oxides of Nitrogen (NOx)		\$7,390						